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Extending Aircraft Engine Lives

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Ladies and Gentlemen,

It gives me great pleasure to appear before you today. I am honored to be the keynote speaker and the topic of extended engine life is extremely important to many of our military and civilian aircraft today. I have been fortunate to have a career where I have found myself working both beginning of new high technology developments of aircraft and aircraft engines to the older or even ancient "Keep them Flying" type programs. The advanced technology development programs always seem to be endowed with plenty of money and the charisma of new technology while the aging programs continually struggle to obtain the necessary support to insert new life in to systems to provide safe and reliable operations.

When I was a young man, I didn't think much about aging. Now that I am older, wiser and much more mature, I have decided that I would like to set some life goals. One of my goals is to live a viable life to the age of 100 which is an age many people are living today due to new medical technology and improved lifestyles from a century ago. My other goal is to score my age or better in golf. Now, when I was thirty, shooting my age in golf seemed an impossibility, and I still haven't seen any of the young pros like Tiger Woods shooting a round of golf where they score anything better than twice their age. However, if I reach 80, I will have a better chance of scoring my age than I do today. As you can see, these two goals are compatible – golf scores of 80 or better when I am 80, providing even more margin as I get closer to a hundred.

Our aging Gas turbine engines also have two goals – one is to achieve a service life greater than the design service life and the other is to reliably and safely perform the mission. Let's consider some o f the aspects of extending

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engine life that must be considered to maintain and upgrade our engine fleets to provide capable systems for longer times.

A Plan – The first item of business is to accomplish our planning to provide for the aging engine upgrades, maintenance and fixes. We have developed plans called " Engine Life Management Plan" for all of our fielded engines. The plan incorporates information relative to the engine design, the fielded usage, the technical criteria to keep the engines operational, and planned fixes and upgrades. The plan is updated on approximately a two-year cycle. The plan provides us with the information necessary to manage the program. It does not prevent surprises and believe me we get our share of surprises, but the plan helps provide the guidance and control for the program. The gas turbine plan is much like the human life plan where we spend a big portion of health care expenditures during the infant period and an even bigger expenditure, as we grow older. As an infant, there are many health costs associated with the birth of a new baby --- hospital, doctor, nurse, shots, and early infant disease. As we mature and age the health care systems take a small, but consistent share of our earnings; however, as we become senior citizens we expend a great amount of the health care monies for a few more good years. I checked some information and the Federal Interagency Forum on Aging Statistics, which indicated that an 85-year-old would have health care expenditures 2.8 times more than a 65-Year-old person would. Gas turbine engines are similar; the cost to bring a new engine into the system is high at the beginning and aging engines are like aging people. How many of you have budgeted for maintenance cost increases of approximately 300% for engines in the last 20 percent of their life? If we want gas turbines to work effectively, we need to be prepared to expend the necessary monies for parts, assemblies, and upgrades to provide safe and reliable operation.

I would like to talk about some of my favorite items for a development engine and how we must reshape your thinking for a fielded engine. We look at engine development as having several key areas, which include the performance, operability, and structural life aspects of the engine. We drive our technologists to provide the maximum performance possible in order to give the warfighter the greatest advantage in operations and tactics. There truly is no second place in combat. Once the warfighter receives their system and discovers the best way to use the system, we must maintain the engines to provide the expected capabilities.

Fielded engine performance and thrust must be maintained. We might think that we could increase engine life at the expense of performance and that a

slight decrease in turbine temperature may provide longer life engines. We must discard this idea as it is important to maintain the engine performance for our warfighters because the way you train is the way you fight! By the same token, the operability considerations give unrestricted throttle movements, stall free operation at high levels of air distortion, and starting of the engine must be maintained throughout the life of the program. This is a key consideration for older engines since the key control components may no longer be manufactured and technology may have evolved to higher levels permitting advanced retrofitable digital controls, but not the capability to maintain current systems. Finally, we come to the structural life of the engine, the item that really limits how long we can keep a fielded engine operating. Our engine designs are normally developed to a fixed scenario – a set of missions to include training, normal operation, and combat. When the operators obtain a weapon system, a new set of operational missions are developed based on tactics, capabilities, and needs. They may use engine structural life at a greater rate than originally anticipated for the program, thus necessitating the need for many new parts, component improvement programs, and repair techniques. This is the issue for engine life and durability in fielded engines. A successful weapon system may have a planned fielded life that is extended and then extended again. We have systems in the USAF that have had long lives, yet have plans which keep them in our inventory for another 10 to 20 even forty years. One system will at retirement, have covered over 60% of the total time for powered flight. These programs require safe and reliable operation for the planned system life expectancy. How do we do this!!! Let me provide you some thoughts in this area.

Sometimes it is necessary to redesign an engine or series of components and sometimes is only necessary to review the processes involved in the maintenance scenario. We are in the process of revitalizing Reliability Centered Maintenance (RCM) in our engines. We started out several years ago looking at the reliability of the engine for the C-5 airlift aircraft. After an in depth review of the maintenance processes, we came to the conclusion that we had to modify our fix-fly-fail-fix maintenance and pay more attention to the maintenance program. We examined a lot of data and discovered that each of our heavy maintenance overhauls produced engines with Time On Wing lives significantly lower than our expectations. We talked to our commercial counterparts, examined our data in detail, reviewed the engine build criteria, and tried a pilot test on our aircraft at Luke and Cannon AFB. The results soon became convincing and we are now implementing Reliability Centered Maintenance for all of our engines

throughout the world. Here are some of our findings. We have increased our engine time on wing by two or three fold for some of our front line fighter aircraft and as a result we are avoiding costly unscheduled engine shop visits. Our flight line, intermediate level, and depot level personnel have all become familiar with the results and through our training program have become advocates of RCM. The improvements have come about as a result of realizing that our maintenance processes and practices directly impact our operations. RCM has become a great success story.

Build Standards and Workscope Planning are important keys to the Reliability Centered Maintenance improvements we have seen. In some cases, an engine coming in for overhaul may include modules with real useful life, but not for the engine that is to be rebuilt to the build standards. In this case a module with some life may be shuttled to another engine in order to align module time for the engine. We may then put an engine back into the field with a limited life as well as one with nearly full life, thus maximizing our utilization while minimizing our overall costs. In every case like this, a working group of engineers, maintainers, and logisticians is needed. They must be fully cognizant of the engine type being overhauled as well as the individual engine serial numbers.

We must monitor and trend our engine usage during operational service. We need to know how the fielded engines are being utilized in order to adequately perform service inspections, maintenance and overhaul. The usage monitoring area is one where I believe technology may have a great impact in the next few years. Computer and information technology schemes will enhance the manner in which we gather, maintain and analyze data. The prognostics aspects of inspections can be greatly enhanced by new equipment in the hands of our trained mechanics. This is an area we need to exploit in order to extend the lives of our fielded aircraft engines.

New technologies are extremely difficult to introduce into fielded engine systems due to the up front design development, and kit costs that must be absorbed by the system. However, many technologies will have a profound impact on the engine operation and life that will return the initial investment many times. These technologies need to be thoroughly understood prior to commitment. Examples include the revision of an engine control system to utilize digital control technologies or a new blade or disk embodying advanced material manufacturing, or design technologies.

Many times we find ourselves in a quandary as a result of fielded engine failures. Failure analysis techniques have to be continually updated and improved to provide the best capabilities to assure we have properly diagnosed the problems and provided the proper solution for the fielded engine community. An example is the trend towards more HCF failures in newer engines and analytical tools to understand these problems.

When you look at an engine you can see that it is made up of many parts and assemblies; some are large and some are small and some are more critical than others. Small parts may cause large problems. Many times we have concentrated on the critical large parts in an engine to provide extended life and small parts begin to fail in a manner that caused larger failure modes. One of the things we do not want to overlook are the small critical parts that individually or collectively may result in catastrophic failure. These parts may also be made of alloys that are not always available and create unwarranted schedule delays if we do not understand their nature. I personally have had a bolt or two that I would have liked to seen redesigned from the beginning.

Material developments may be key to enhancing the life of fielded engines. When we find we have some materials in an engine that limit the life and a problem develops, we start looking for material alternates or newly developed materials. These materials may provide relief to a short-term issue or may provide parts than enhance the fielded engine life. An increase in the Turbine Inlet Temperature of 50 degrees may cut the life of a turbine blade in half.

Repair capabilities for blades, disks, seals, and key engine components such as fuel controls may either enhance our overhaul capabilities or grind thing to a halt. We are continually looking for better materials and repair techniques to keep our fielded engine fleet operating at minimal costs. In one instance we have our research laboratories working on the repair of a new technology combustor and at the same time supporting the Air Logistics Centers in the repair of fielded engine combustors. We work hard to bring the technology producers together with the technology consumers.

Commercial airline engines also have aging engines and the desire to have an engine stay on wing for a longer time prior to overhaul. Recently (Jan 01) the US FAA issued an Advisory Circular with new criteria for engine rotating parts. The AC describes the acceptable means for showing compliance applicable to the design and life management of high energy

rotating parts of aircraft gas turbine engines. The AC includes both a life management plan and damage tolerance analysis for rotating parts.

Lastly, I would like to say a few words about High Cycle Fatigue and engine durability. The engine life cycle has many challenges. We have had operability problems with inlet distortion in the 60s and 70s that we have learned to deal with. We had engine structural integrity problems we had to deal with in the 70s and 80s and we have been dealing with High Cycle Fatigue issues throughout the 1990s. We have expended large sums of money to understand the High Cycle Fatigue problems that have impacted some of our front line engines and have developed new analytical tools to understand the phenomena and put in place new design mechanisms for new parts and engines. We feel that we now somewhat understand the HCF issues and need to move on to extending the life of our engines with improved durability initiatives. We must consider durability early in our research and development programs; and build engines that will last for the long expected field service usage lives. I believe the durability issues of the early years of the 21st century will enable us to continue to extend the lives of current operational engines and provide improved engines for the modern air warfighter.

The challenge we have today is to keep the aircraft flying with reliable, safe, high performance engines.

Thank You, If you have any questions I will be pleased to provide a response.